Trends in Picture Communication

Prof. Dr. Joachim Speidel *)
Philips Kommunikations Industrie AG, Nürnberg

1. Introduction

In the past years significant progress was made with digital transmission of audiovisual services and most interesting trends are visible for the future. Such applications encompass interactive services, like videoconferencing (Fig. 1), ISDN-videophone (Figs. 2a,b), storage of moving video and audio in computers or on CD, e.g. for multimedia applications (Fig. 3). For distribution services, there is an unbroken trend form TV to HDTV (Figs. 4a,b). Strong emphasis is on compressed digital video even for transmission to the home.

2. Bitrates and Applications

The video signal, which is the basis of all these applications, generates after digitization a high bit rate of about 166 Mbit/s for studio-quality pictures and even about 1,2 Gbit/s for HDTV, as is well known. In Tab. 1, bit rates and applications are summarized.

Interactive Services

For the interactive services videoconferencing and videophone, extremly high data compression is employed yielding bit rates from about 48 kbit/s to 1.5 and 2 Mbit/s, which can be handled by the emerging ISDN. For storage of moving video, a medium size bit rate of 1.15 Mbit/s is a good compromise between picture quality and storage time, which is about 1 hour of moving video on a CD.

*) The author is now with the Institut für Nachrichtenübertragung, University of Stuttgart, Breitscheidstr. 2, 7000 Stuttgart 1.

Contribution Services

Contribution services for program exchange between studios are a second important application. The degree of data compression is chosen such that definitly no visible impairment of signal quality occurs. Starting from the source with 166 Mbit/s for studio-quality signals, the bit rate can be lowered to about 34 Mbit/s, as listed in Tab.1. For HDTV-signals, the source bit rate of 1.2 Gbit/s is reduced to about 140 or 155 Mbit/s. Transmission is done through leased lines in the telecommunication network of the existing Plesiochronous Digital Hierarchy (PDH) or in the new and emerging network of the Synchronous Digital Hierarchy (SDH).

Distribution Services

The third important application is distribution of TV- and HDTV-signals to the home. Presently, analog transmission is used on cable (CATV), terrestrial and satellite links. In USA, there is a strong trend towards digital transmission of additional TV-programs at low bit rates to the consumers in the CATV networks. This will be considered later in more detail. For the new HDTV-world, three solutions are under serious considerations: Japan has proposed MUSE, followed by the European proposal HDMAC. Stimulating discussions started recently through proposals from USA on compressed digital HDTV to be transmitted through analog channels using MODEM technology. This method is often called "digital" compared to "analog" HDMAC, which creates some confusion. Note, that MUSE and HDMAC are digital compression techniques, as well. E.g. the resulting bit rate for HDMAC is about 160 Mbit/s. However, different from the modem-technique, the digital HDMAC-signal is converted into analog format, composed of multiplexed luminance and colour-difference signals, before transmission to the consumers. Thus, it becomes a TV-signal rather than a data modem signal on the line.

3. Source Coding and Transmission for Interactive Services

A great step forward on source coding of moving video was achieved by an international collaboration of experts from industry, research, network- and service providers within a CCITT experts group. As a result, the recommendation H.261 was finalized end of 1990. The method is dedicated to video conferencing and ISDN-videophone. However, due to its high performance, this method is taken as a platform for further developments for storage, multimedia, digital TV and HDTV applications, as described subsequently. In Fig. 5, the source encoder is depicted comprising interframe DPCM, Discrete Cosine Transform (DCT), motion compensating prediction, Huffman and runlength coding. The quality of a moving picture generated by the coder and displayed on a monitor with max. 9 inches diagonal is ranked as normal TV by non experts. The bit rate at the input of the transmission buffer varies with time. The buffer caters for smoothing to achieve a constant output bit rate, as required by state of the art telecommunication networks. With future networks of asynchronous transfer mode (ATM), variable bit rates are welcome, and the buffer size can be reduced as a consequence. The impact of packet loss due to transmission errors on picture quality is subject for research at present. There are promissing first results indicating that the procedures can be made very robust with simple additional means to cope with packet loss rates of 10^{-3} or even higher in ATM networks.

In Tab. 2, the work program of the ISO/IEC Motion Picture Experts Group (MPEG) is listed. Plattform is the coder in Fig. 5. However, for storage applications, several trick modes, like "fast search", "backward run" etc., are required. For a pure interframe coder, "backward run" is a very difficult task. As a consequence, a cyclic intraframe prediction mode has to be introduced. Significant improvement of picture quality is gained by additional prediction modes, as illustrated in Fig. 6. Further targets of MPEG are listed in Tab. 3. Picture quality achieved so far is remarkable good. Even critical experts are impressed.

4. TV and HDTV

At the beginning of the HDTV discussion in the 1980's, USA was quite reluctant and it seemed to the Europeans that the US considered themselves as consumers and the Japanese as producers. This attitude has changed dramatically. Strong forces were established in the last years: AT & T, GI, David Sarnoff Research, Thomson, Philips North America and others are working on solutions for digital TV and HDTV distribution, different from MUSE and HDMAC/D2MAC. In Fig. 7, the principal block diagram is shown. The transmitter is composed of the source coder for TV and audio, the channel coder and the VHF/UHF transmitter. All transmission media are under consideration: Terrestrial, satellite and CATV. In Fig. 8, the transmitter is depicted in more detail. Given a bandwidth of 6 MHz, a modulation scheme with 16 levels can achieve about 20 Mbit/s which provides about 14 Mbit/s for the HDTV-signal, the rest is used for audio and forward error correction. A 64 level modulation would even increase the net HDTV bit rate to 25 Mbit/s. Quadrature amplitude modulation (QAM) is well suited for cable networks. For terrestrial and satellite transmission

OFDM (Orthogonal Frequency Division Multiplex)

COFDM (Coded OFDM)

SS-CDMA (Spread Spectrum Code Division Multiple Access)

are under consideration as well, providing good performance under multipath reception conditions, however consuming more bandwidth or bit rate.

Besides digital HDTV transmission -pilot projects are planned for 1993/94 in USA- digital transmission of normal TV in cable networks is of paramount interest for the near future. This is an extremly market driven issue. Major service operators (MSOs) are aiming at a billion dollar business by providing latest films for CATV subscribers on a pay per view basis (Tab. 4). Consumers, at present renting their films at a videothek, should stay in their living rooms watching pay per view. Total turnover of videotheks is estimated to several billions US $ per year in USA, and CATV service operators would like to take a significant share out of that. "Near instantaneous movies" should provide the consumers with the same film every 15 minutes to avoid inconvenient waiting times. As the number of conventional channels is constant and limited in existing CATV networks, additional channels have to be provided by putting up to 6 digital TV signals into 6 MHz bandwidth. Also tabo-channels are planned to be used. As a consequence, the TV-signals have to be encoded at 3 to 4 Mbit/s, each. Cable operators impose the strong requirement that the totals system must have the potential to be upgrated to HDTV. In 1992/93 pilot projects will start. Operation of final system is planned for 1994/95. As shown in Fig. 9a, the expectation of CATV connections in the coming years is leveling off, if no new services are introduced in the USA. This trend is predicted to change dramatically by the new ideas outlined.

The CATV landscape in Europe is different from USA (Fig. 9b). Whereas USA shows almost full coverage, this is only the case in a few countries in Europe, e.g. Belgium and The Netherlands. Large countries, like Italy, Spain, Portugal and others, are still at the very beginning. At present, the largest CATV network in Europe with about 11 Mio. connections (about 19 Mio passed) is located in Germany, mainly operated by the German Telekom. As a consequence, digital transmission of TV to the home is also an important issue for terrestrial and satellite links in Europe. Also the strong increase in numbers of portable TV sets, and even mobile sets in the future, has to be taken into consideration. Within the next 15 years, compressed digital TV at bit rates of 3 to 10 Mbit/s can be a serious candidate to replace PAL and SECAM in Europe. Various working groups have been established recently in Germany to look into the problems.

5. New cable networks in the local loop

More and more providers of telecommunication networks and services would like to enter into the business of CATV network and service operators and vice versa. There is also a vital discussion about removal of stringent governmental regulations, existing in various countries around the world. The great challenge is a combined network on optical fiber basis in the local loop, which is the area form a CATV head end or a telecom switching office to the consumer's house. However, the economy of such a new network has to be measured merciless with respect to conventional solutions. In doing so, life cycle costs should be takten as a criterion, rather than just investment costs, to visualize synergies for operation, administration and maintenance.

At present, two networks exist side by side, which are cost optimized separately: Branch and tree structure for CATV (Fig. 10) and a star topology for interactive telecommunication services, mainly telephony (Fig. 11), as is well known.

A combined optical network with full fletched star structure turns out to be too expensive in the near future. A branching structure, as shown in Fig. 12, is the preferred solution /1/. Signals from the center are fed via a single fiber into a first splitting node, where several fibers are connected. A second arrangement of splitters is in the vicinity of a group of subscribers. If no electrical or optical amplifiers are in this "fiber fabric", the network is called a passive optical network (PON). Obviously, the topology is a concession for TV-distribution. For interactive services, transfer modes different from those used in present local loop cable networks have to be applied, e.g. TDMA (Time Division Multiple Access) or ATM in the future. In Germany several pilot projects with this technique have been implemented and successfully tested by equipment manufacturers and German Telekom. In 1993, about 200 Thsd. households will be connected in East Germany.

Until 1995, this figure is expected to rise up to 1.2 millions.

This is an exciting perspective for network carriers, service providers, the equipment industry and last but not least - the consumers.

Lit.:

/1/ J. Speidel, T. Swanenburg, H. Tamm,
New fiber network in the local loop for telecommunication and
TV-distribution services,
Philips Telecommunication Review, Sept. 1991.

Services and Bitrates

- **Interactive Services**

Transmission:	**Videoconferencing, ISDN-Videophone** **48 kbit/s - 2 Mbit/s (ISDN)**
Storage:	**CD-ROM, Multimedia** **1.15 Mbit/s**

- **Contribution Services (studio - studio)**

TV:	**166 - 155 - 140 - 70 - 34 Mbit/s**
HDTV:	**1200 - 622 - 565 - 155 - 140 Mbit/s**

(SDH/PDH-Network, Leased Lines)

- **Distribution Services (to the home)**

TV:	**Analog, ca. 4 Mbit/s (USA)**
HDTV:	**HDMAC (Europe), MUSE (Japan), 20 Mbit/s (USA) ?**

Tab. 1: Applications of moving pictures and ranges of bit rates

MPEG / ISO-IEC

Coding of moving images at 1.2 Mbit/s for storage and retrival algorithm based on p x 64 kbit/s with enhancements:

+ cyclic intraframe mode for random access of stored pictures
+ fast search forward/backward features
+ frame interpolation for improved picture quality
+ Audio encoding 64 kbit/s (Layer 3) - 192 kbit/s (Layer 1)

Tab. 2: Work program of Motion Picture Experts Group (MPEG 1)

MPEG / ISO-IEC

Further targets

- Moving images at 2 - 10 Mbit/s, studio quality (MPEG 2, 1990 - 92)
- HDTV up to 40 Mbit/s (MPEG 3, 1993 - 95)
- Flexible solution with various stages of compatibility

Tab. 3: Future Work of MPEG

Trend in USA

- "Pay per View"
- "Near instantaneous movies"
- Up to 6 digital TV-signals within 6 MHz channel

Tab. 4: Trend in USA: Digital TV for Pay per View

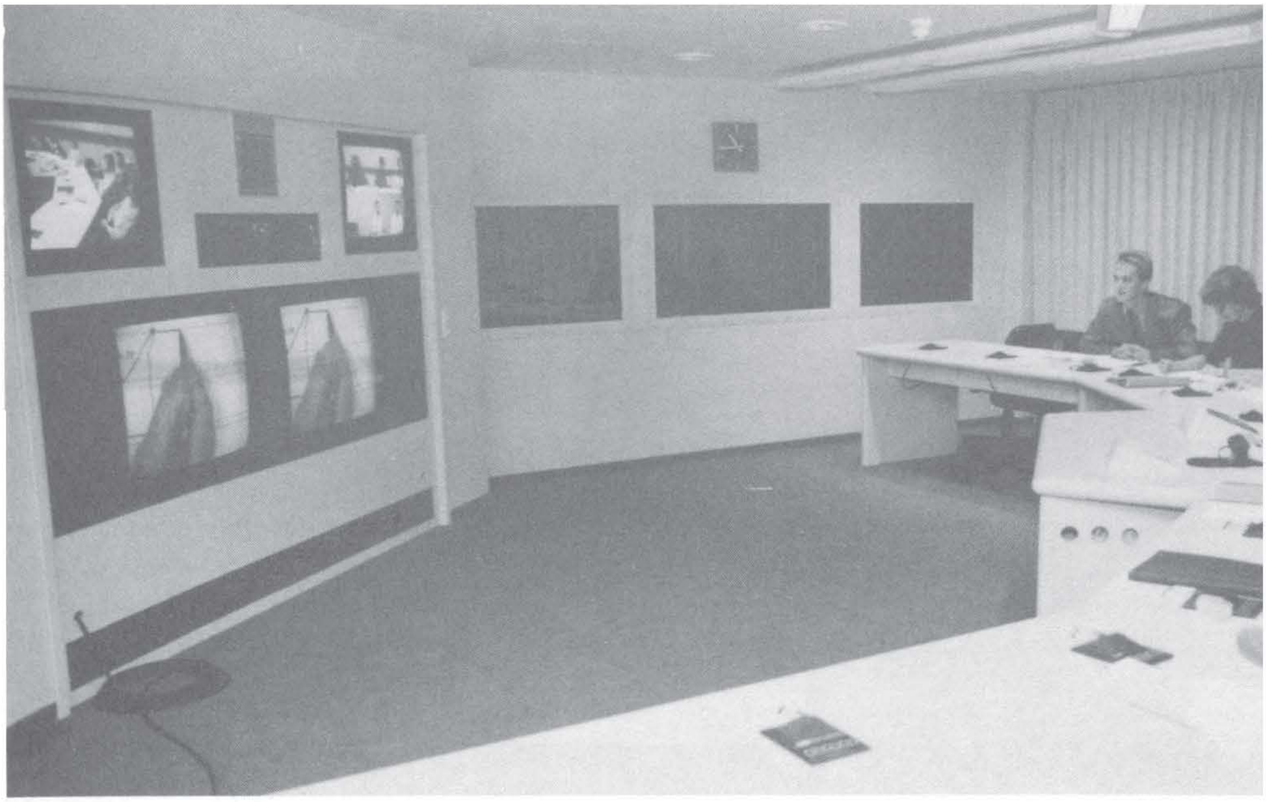


Fig. 1: Videoconferencing, application teleteaching

Fig. 2a: Videophone application

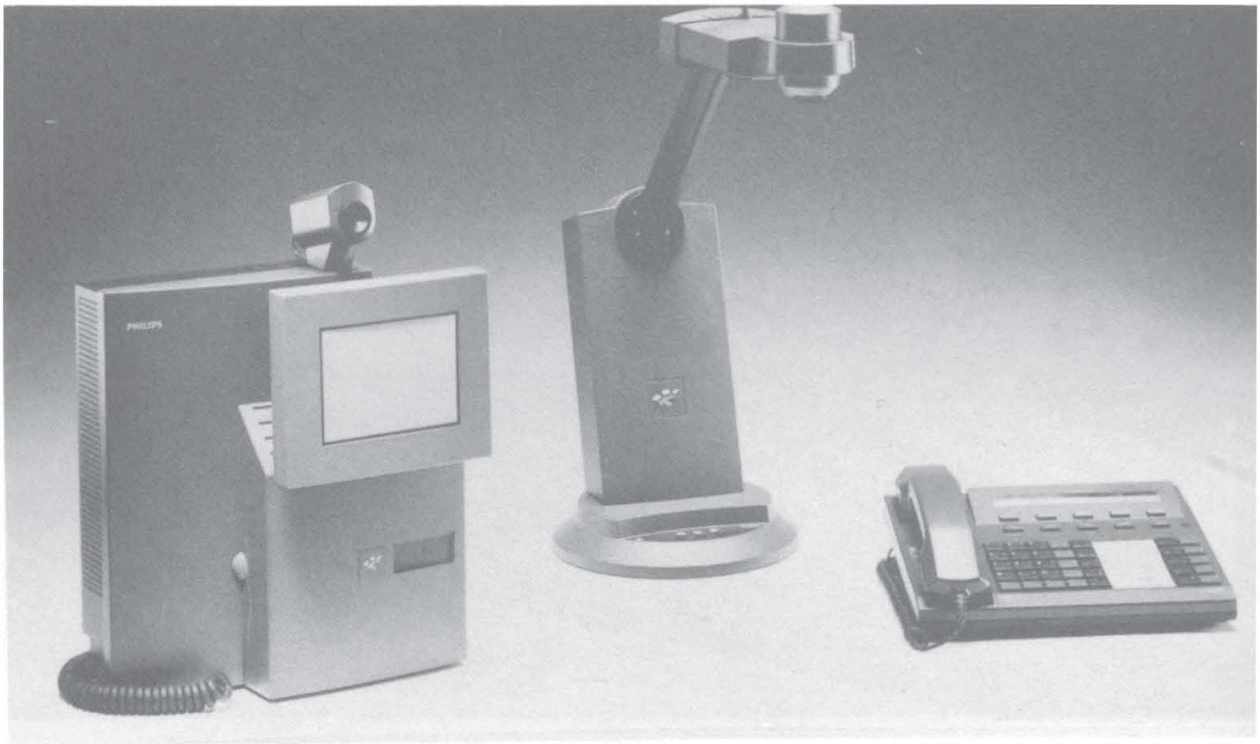


Fig. 2b: ISDN videophone set (from left to right: miniaturized codec with CCD camera and LCD display, still picture camera unit, ISDN telephone)

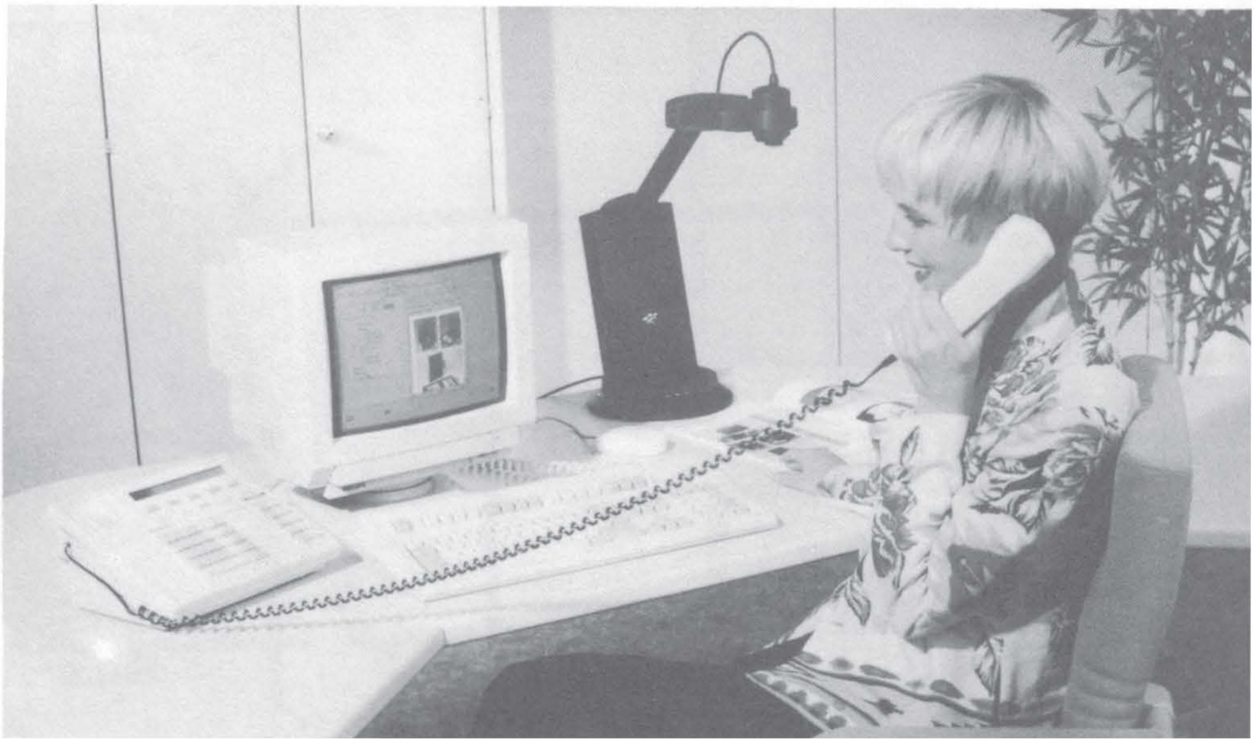


Fig. 3: Multimedia application

a)

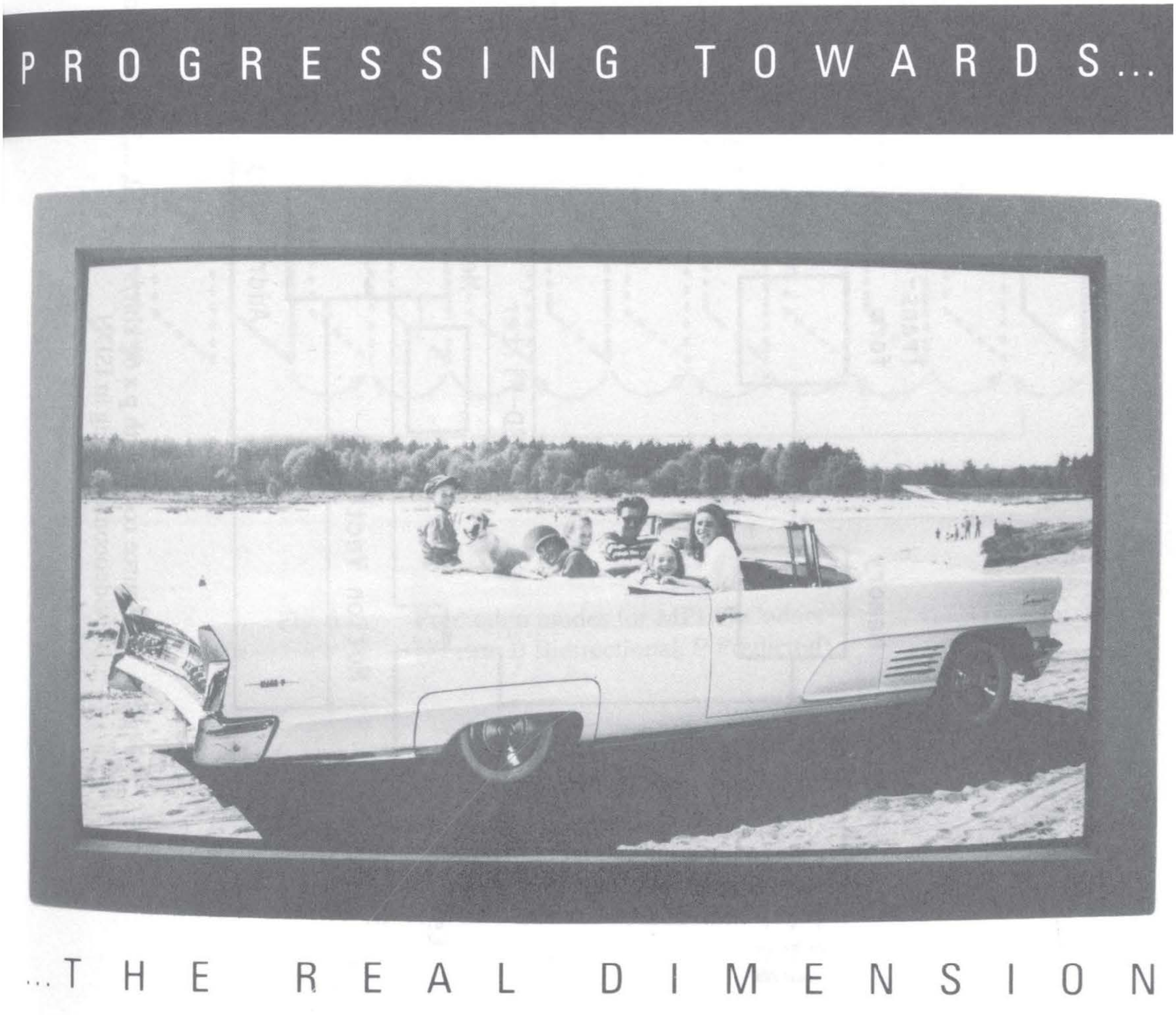


Fig. 4: a) Normal TV
b) High Definition TV (HDTV)

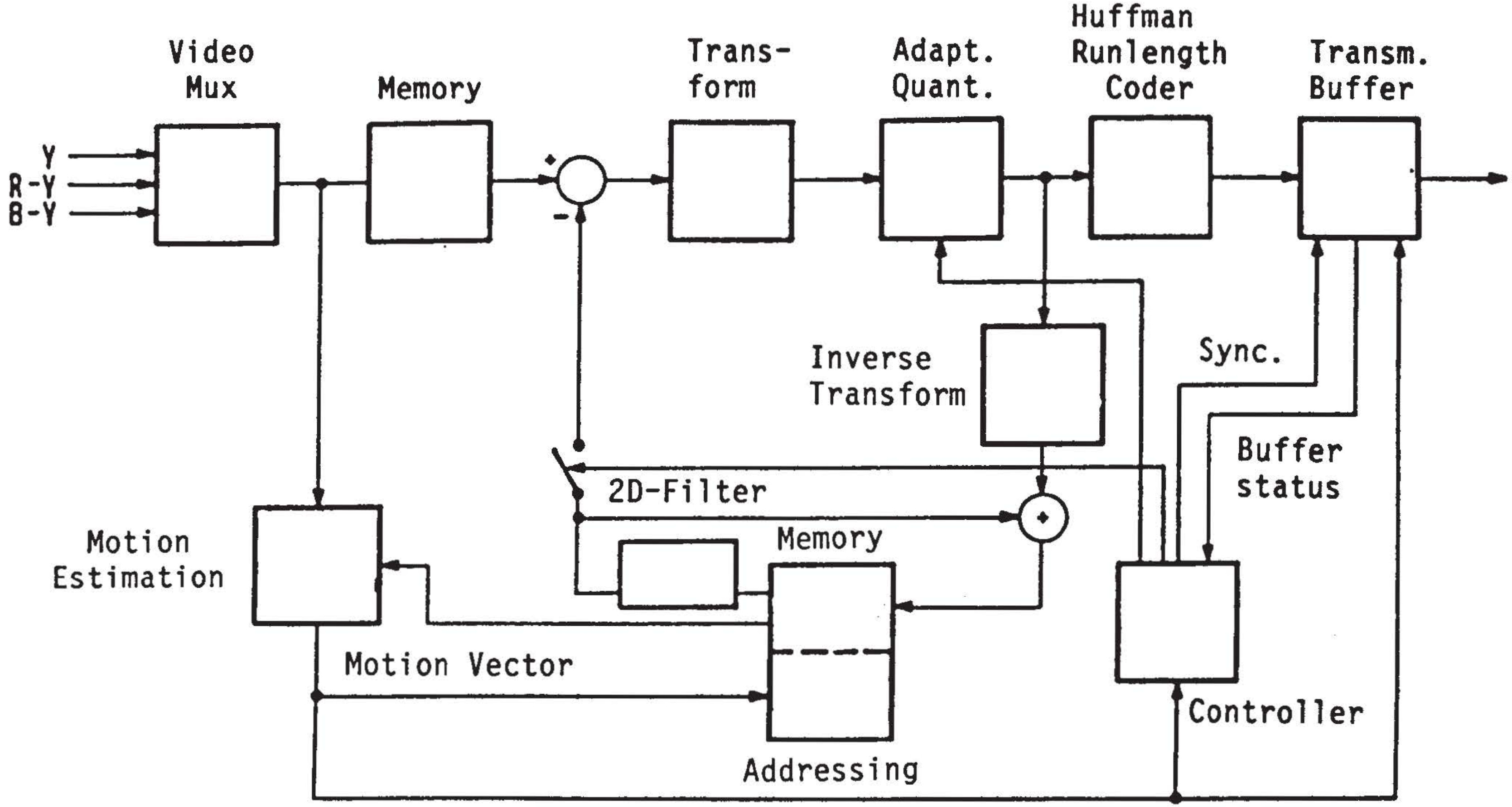


Fig. 5: Source coder with p x 64 kbit/s (p=1, 2, ...,30) for videophone and videoconferencing in ISDN

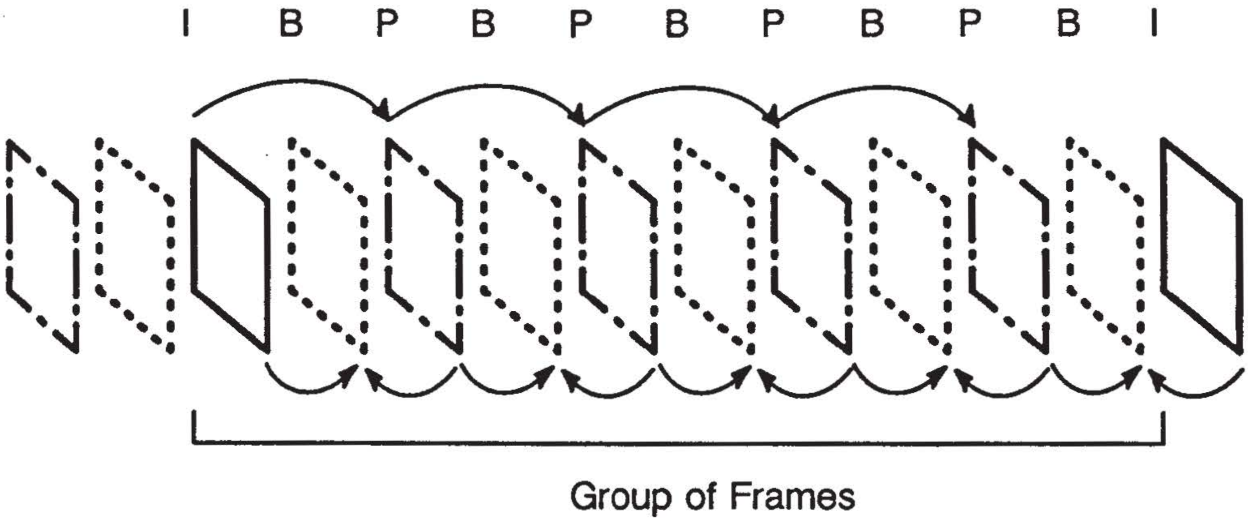


Fig. 6 : Prediction modes for MPEG-Coders
(I Intra, B Bidirectional, P Predicted)

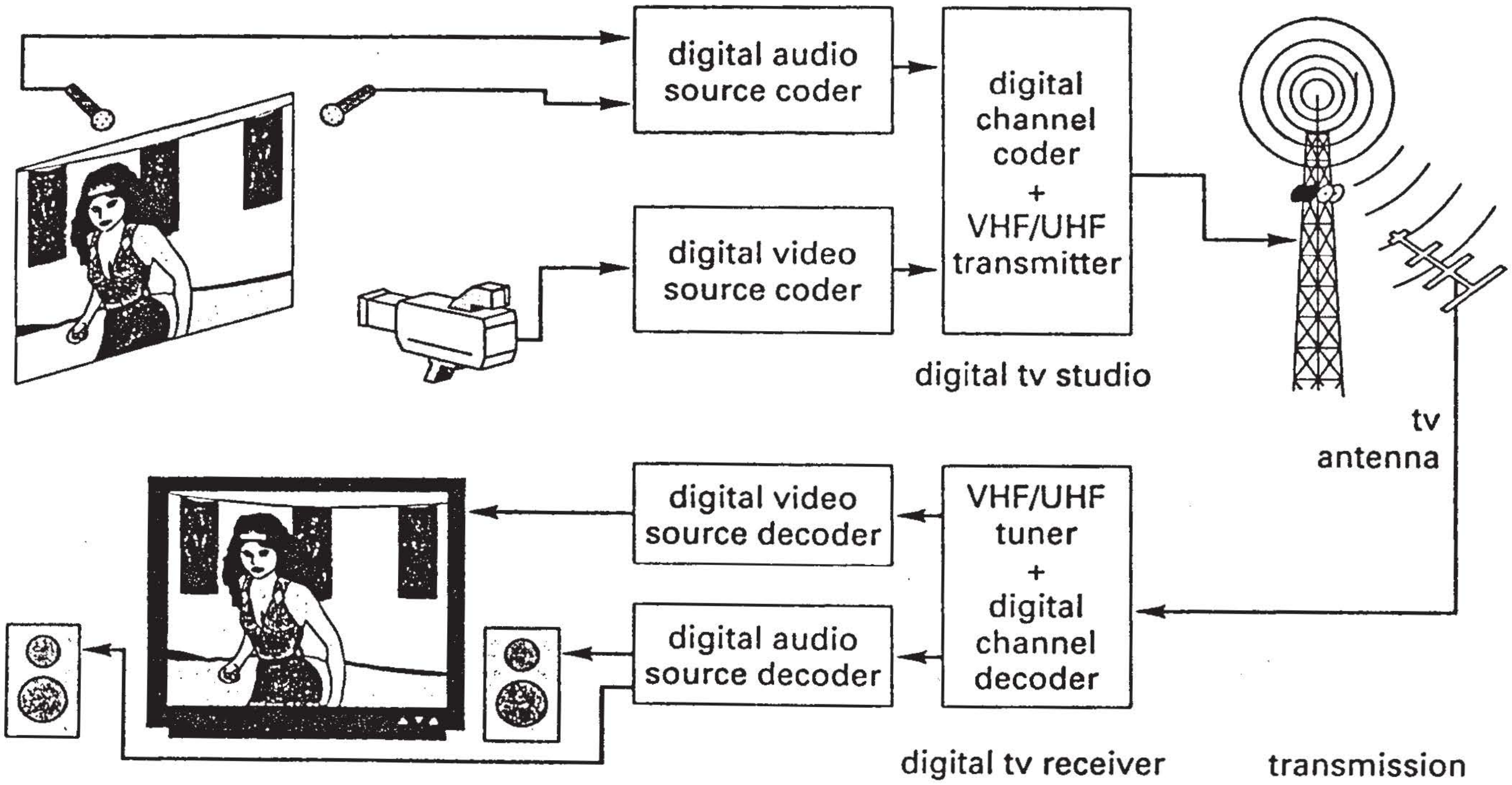


Fig. 7: Digital TV and HDTV transmission to the home

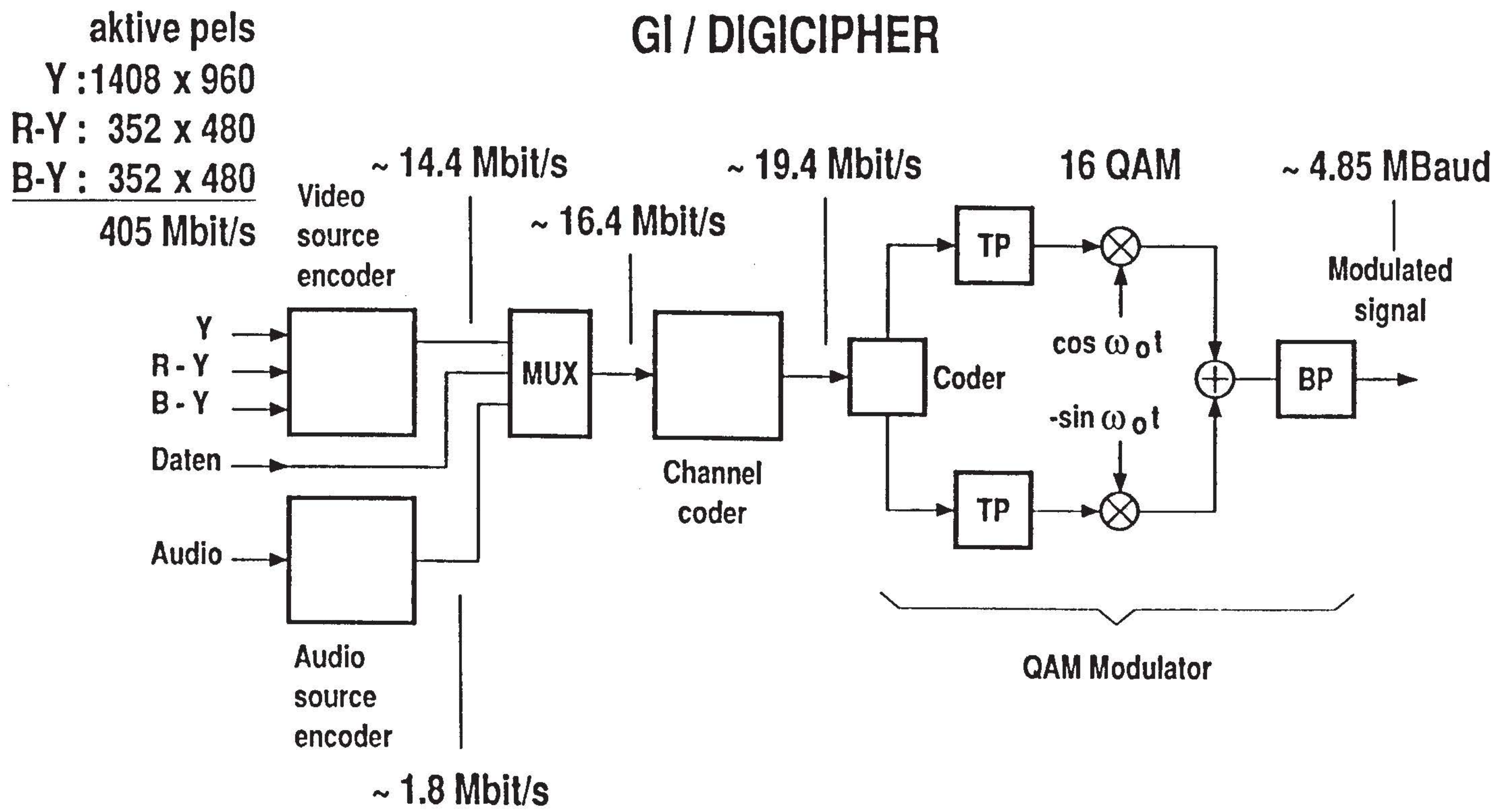
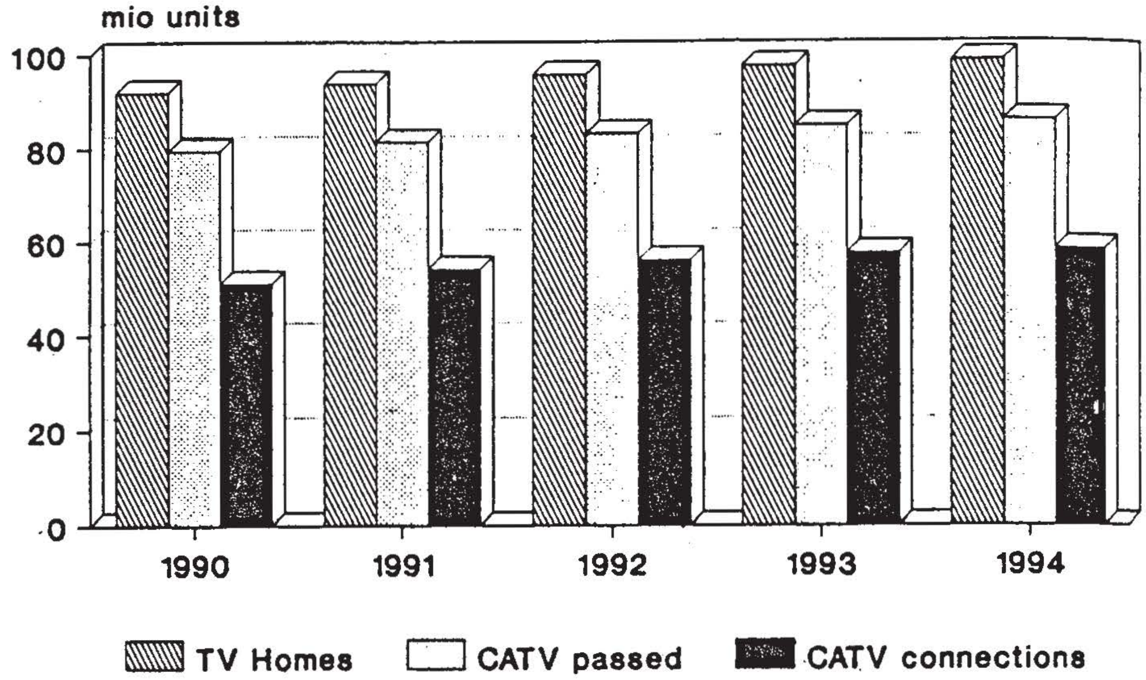
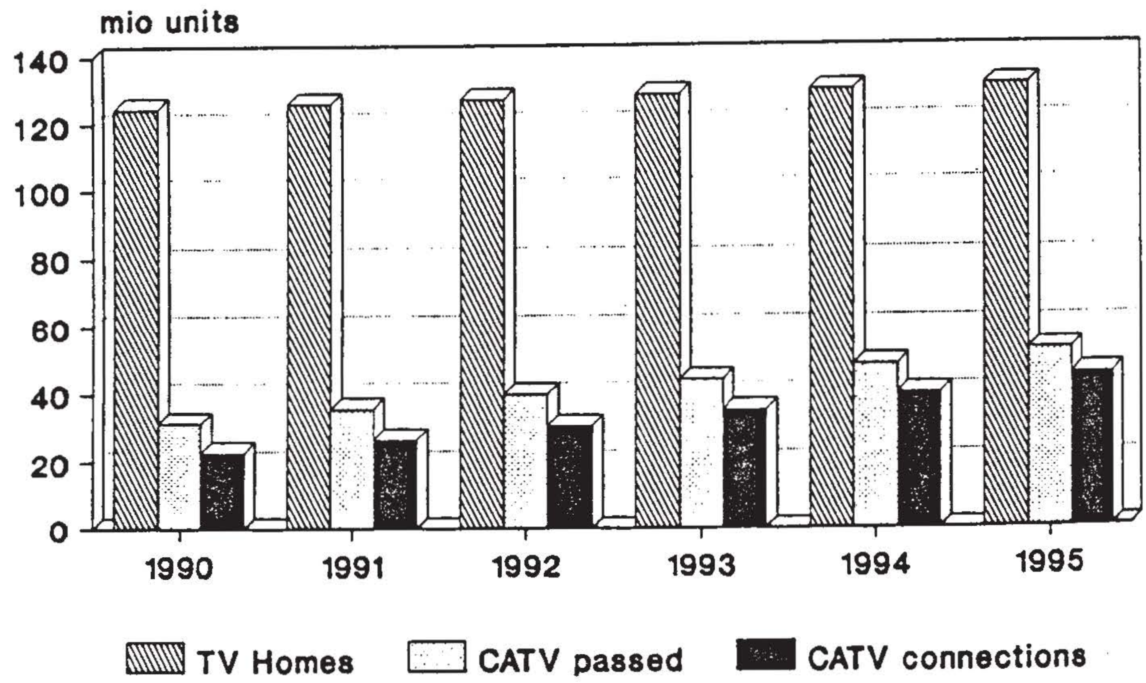


Fig. 8: Transmitter for digital TV and HDTV



a)



b)

Fig. 9: CATV penetration with expectation for the future (excluding impact of new services)
a) USA
b) Europe

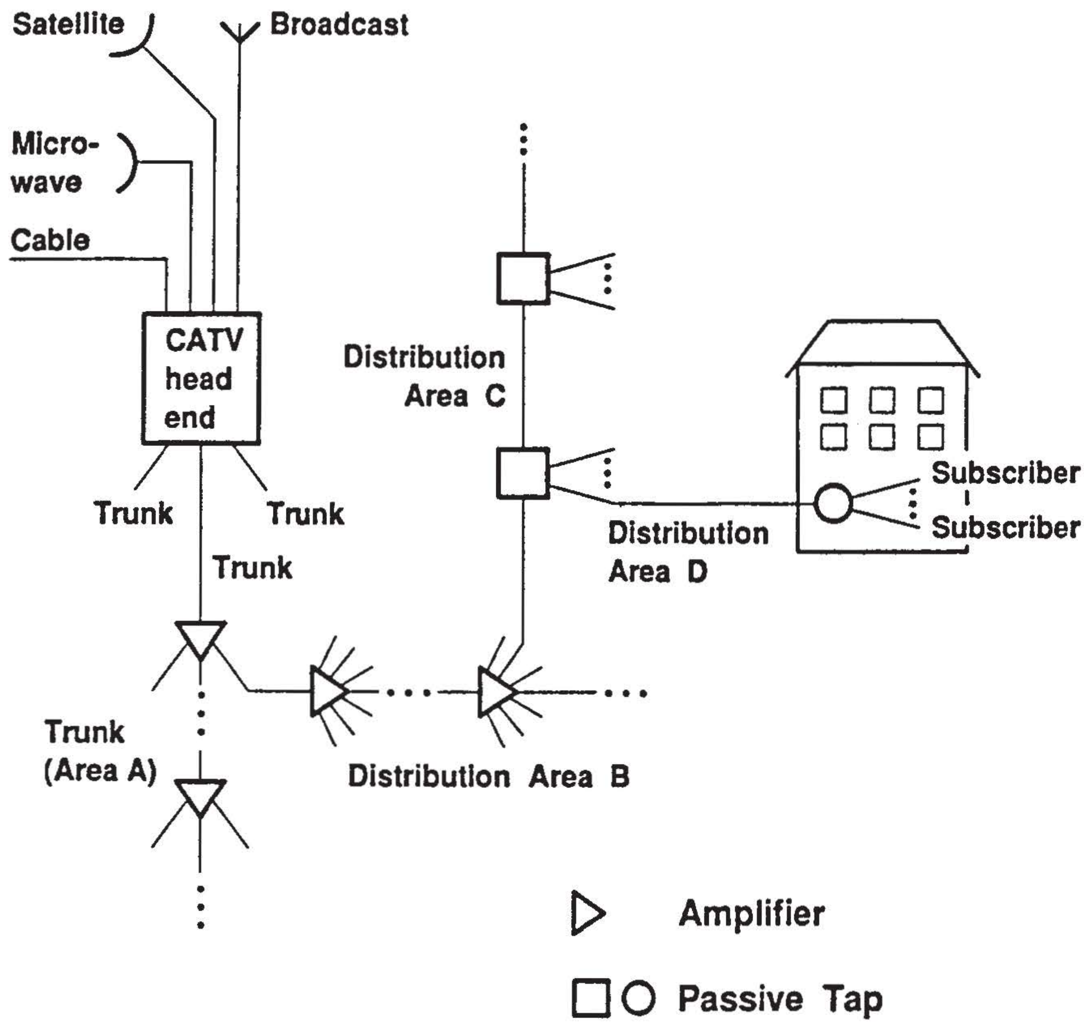


Fig. 10: Existing CATV network with branch and tree structure

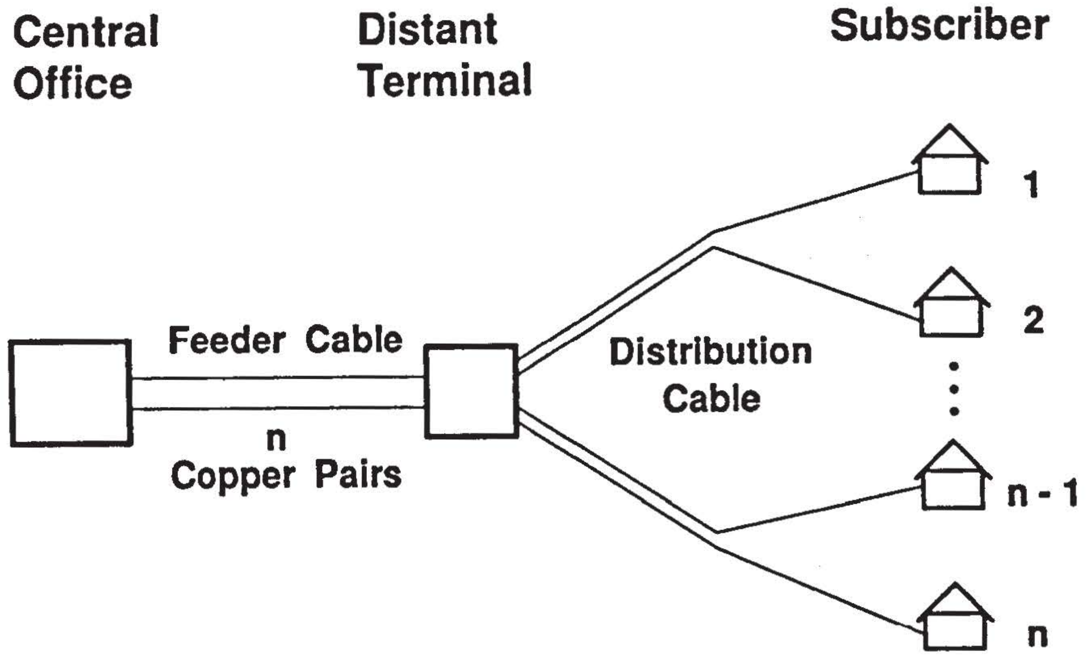


Fig. 11: Existing telecommunication network in the local loop with star structure

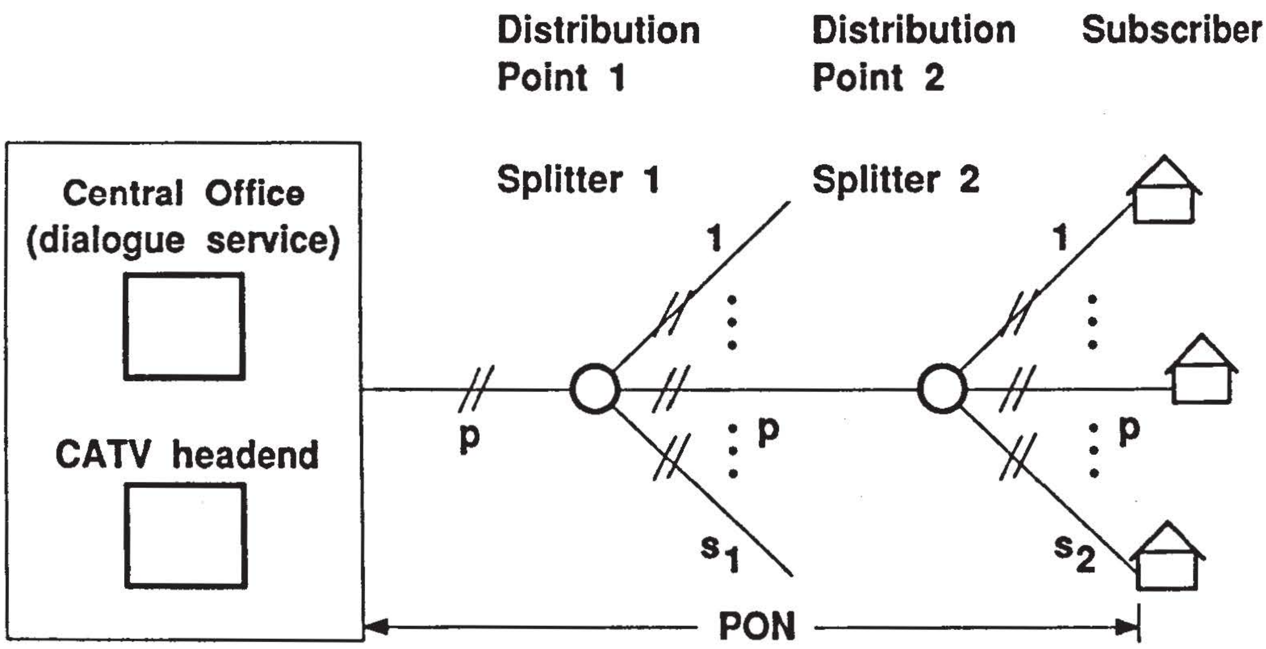


Fig. 12: Passive optical network (PON) for distribution and interactive services